UNIVERSITY OF EDUCATION, WINNEBA

RESPONSE OF OMANKWA MAIZE VARIETY TO NPK AND BIOCHAR SOIL AMENDMENT

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MASTER OF EDUCATION (M.ED AGRICULTURE)

2022

UNIVERSITY OF EDUCATION, WINNEBA

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(7191910031)

A DISSERTATION IN THE DEPARTMENT OF CROPS AND SOIL SCIENCES

EDUCATION, FACULTY OF AGRICULTURE EDUCATION,

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, UNIVERSITY OF

EDUCATION- WINNEBA, IN PARTIAL FULFILMENT

OF THE REQUIREMENTS FOR THE AWARD OF THE

DEGREE OF MASTER OF EDUCATION IN AGRICULTURE

(CROP SCIENCE)

JULY, 2022

DECLARATION

STUDENT'S DECLARATION

I, Jacob Asare Konadu declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

……………………………………… ……………………………………

JACOB ASARE KONADU Date

SUPERVISORS' DECLARATION

I hereby declare that the preparation and presentation of this project work was supervised in accordance with the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

……………………………………… ……………………………………

DR. BERNARD EFFAH Date

ACKNOWLEDGEMENTS

I thank the Almighty God for this beautiful piece of work. For it is His bountiful grace and divine protection that has brought me this far. I also express my sincere gratitude and appreciation to Mr. Isaac Tete Mensah, a Senior Lecturer at the Department of Crop and Soil Sciences Education, University of Education, Winneba, for the support in conceptualizing the research topic. The resourceful and untiring supervision of this work by Dr. Bernard Effah, a Senior Lecturer at the Department of Crop and Soil Sciences Education, College of Agriculture Education of University of Education, Winneba, is extremely appreciated. The encouragements from Prof. Mrs. Margaret E. Essilfie Coordinator Graduate Studies, Faculty of Agriculture Education of University of Education, Winneba is also highly remembered and appreciated.

Much thanks to Mr. Kofi Amponsah and Mr. Alex Otabil-Assistant Registrars at the Department of Crop and Soil Sciences Education, Mr. Eric Opoku Mensah (CSIR – Plant Genetic Resources Research Institute, Bunso) for their support. I offer my profound gratitude and appreciation to Mr. Bernard Owusu Kwarteng, Mr. Augustus A. Antiedu (AAMUSTED Farms, Mampong), Miss Hetty Amoah, Mad. Matilda Frimpong (CRI, Kwadaso), Mad, Judith Frimpong (SRI, Kwadaso) for your assistance and many sacrifices offered to me. My course mates -Samuel Annim, Michael Weittey and Charles Osei have been very helpful to me. Thanks also to my in-laws for their advice and encouragement. To my parents and siblings, I say thank you for your prayers and encouragements. To all my friends and classmates, I thank you for your support over the years.

Finally, I thank my dear wife (Phyllis Asare), and daughter (Eunice Asare Konadu) for standing by me and making the seemingly difficult journey a lively one.

DEDICATION

I dedicate this work to my dear wife (Phyllis Asare), my daughter (Eunice Asare Konadu) and my parents (Mr. Paul Asare and Mrs. Diana Asare).

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
CRI	Crops Research Institute
FAO	Food and Agriculture Organization
GENSTAT	General statistics
NPK	Nitrogen Phosphorus Potassium
K	Potassium
SSA	Sub-Saharan Africa
GHG	Greenhouse Gas
MoFA	Ministry of Food and Agriculture
N	Nitrogen
Mn	Manganese
Cu	Copper
B	Boron
Zn	Zinc
OC	Organic Carbon
PFJ	Planting for Food and Jobs
RCBD	Randomized Complete Block Design
UNDP	United Nations Development Program
WAP	Weeks After Planting

ABSTRACT

The study investigated the effect of NPK and biochar soil amendments on some growth and yield parameters of Omankwa maize variety. The experiment was laid in Randomized Complete Block Design with three replications. The four treatments used included: 250 kg/ ha NPK, 6 tons ha-^{1} biochar; a combination of 125 kg/ ha NPK and 3 tons ha^{-1} biochar and a control. Data were collected on phenological, growth and yield parameters. The findings from the growth parameters shown that the maize plants treated with a combination of 125 kg/ ha NPK and 3 tons ha^{-1} performed better in terms of stem girth, number of leaves per plant, leaf width, leaf length and plant height than all the other treatments. Yield findings also indicated that maize plants that received NPK and biochar treatment recorded a significant increase in cob length, cob diameter and 100 seed weight. Furthermore, results from the phenological parameters which included germination percentage, days to 50% tasseling, days to 50% silking and days to 50% maturity revealed that maize plants treated with the combination of NPK and biochar did well than all the other treatments. It was concluded that the combination of NPK fertilizer and biochar improved the fertility of the soil and promoted growth and yields in maize.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Maize forms a significant component of staple food in Ghana. It is used in preparing various dishes for adults and infants. It is also used in feeding of poultry (Palacios-Rojas *et al.,* 2020). The brewery industrial used it for the production of local beer (Asana). Increase in demand of the commodity has resulted in expanding production in many areas in Ghana. Despite the importance of maize to the teeming population of Ghana, its production has not met the food and industrial requirement of the country. The average maize yield in Ghana which is 1.92 metric ton/ ha is low and remains one of the lowest in the world, much lower than the average for Africa South of the Sahara which is 2.0 metric ton/ ha (Yeboah, 2013; Ragasa and Chapoto 2017; Wongnaa *et al.,* 2019).

This low average production is attributed to soil deterioration from depletion of nutrients which is a serious global problem according to Aikins *et al.* (2012) and Issa *et al.* (2016).

The problem of infertile soils and variable climatic conditions affect potential yield of maize (Chabala *et al.,* 2015) and as a result decreasing household income. One feasible measure to increase soil fertility is addition of biochar (Kätterer *et al.,* 2019). Biochar is a stable form of charcoal produced from heating natural organic materials (crop biomass, woodchips, manure, and other agricultural waste) in a high temperature of 1000 °C, the process is known as pyrolysis (Berek and Hue, 2013). The addition of biochar as amendment materials to agricultural soils is receiving much attention due to the apparent benefits of biochar to soil quality and enhanced crop yields, as well as the potential to gain carbon credits by active carbon sequestration (Major, 2010).

Studies conducted by Hunt *et al.* (2010) showed biochar aiding in: soil nutrients improvement, increase cation exchange capacity in the soil, soil acidity reduction, improve soil structure, enhanced plant nutrient use efficiency of potassium, improve water-holding capacity and carbon sequestration. In addition to the potential for carbon sequestration, biochar has numerous benefits when added to the soil (Major, 2010). It prevents the leaching of nutrients out of the soil, makes nutrients available for plant growth, increases water retention (Major *et al.,* 2009) and reduces the amount of fertilizer required. Biochar also decreases N_2O and CH_4 emissions from the soil, thus reducing greenhouse gas (GHG) emissions (Khura *et al.,* 2014). One of the most immediate uses of biochar is in switching from “slash – and – burn” to “slash – and – char” to prevent rapid deforestation and subsequent degradation of soils.

1.2 Problem Statement and Justification

Cost of inorganic fertilizers in Ghana is rendering farmers unable to invest into fertilizer application to increase crop production (Yawson *et al.,* 2010; Fearon *et al.,* 2015). Therefore, the application of biochar or in combination of inorganic fertilizers could be a possible way to improve crop yield while reducing cost of production. The present study therefore tends to determine how Omankwa maize variety will respond differently to NPK fertilizer, biochar and the combination of the two soil amendment strategies. Thus, to identify possible ways of reducing cost of fertilizer applications and increasing yield.

Omankwa maize variety is one of the new varieties of maize which is drought tolerant in Ghana (Abate and Vision, 2015). It was released in Ghana in the year 2010 by the Council for Scientific and Industrial Research. It has high genetic vigour and desirable traits such as high yielding and early maturity. The variety was released to address problems such as nutrient uptake under unprecedented soil fertility decline, along with sporadic weather change (Gondwe and Nkonde, 2017). It is most suitable for forest and forest transitional zones. It is expected to produce about 5 t/ha on the average. Economic benefit analysis also revealed that the best option for highest net benefit is the cultivation of hybrid varieties (Iken and Amusa, 2004). Furthermore Beche *et al.* (2013) made several demonstrations on the beneficial qualities of hybrid maize, due to its inbuilt safety measures of hybrids, despite the fact that farmers require to buy seeds for each planting season. In order to improve the current low yields of maize in Ghana, farmers need hybrid seeds together with adequate levels of fertilizers. It is on this basis that Omankwa maize variety which is hybrid was used for this research.

1.3 Main Objective of the Study

The main objective of the study was to determined how Omankwa maize variety will respond differently to NPK fertilizer, biochar and its combination.

1.4 Specific Objectives of the Study

The study shall specifically determine;

1. the performance of Omankwa maize variety to 250 kg/ ha NPK Fertilizer application.
2. the performance of Omankwa maize variety to 125 kg/ ha NPK Fertilizer and 3 t/ha biochar application.
3. the performance of Omankwa maize variety to 6 t/ha biochar application.

1.5 Hypothesis

H_i: Omankwa maize variety will respond differently to NPK fertilizer application, biochar application and combination of NPK fertilizer and biochar application.

H_0: Omankwa maize variety will not respond differently to NPK fertilizer application, biochar application and combination of NPK fertilizer and biochar application.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Uses and Importance of Maize in Ghana

Maize is the most widely grown cereal crop in Sub-Saharan Africa and covers an estimated 25 million ha, largely on smallholder farms. It accounts for about 20% of the caloric intake of about 50% of the population in Sub-Saharan Africa (Badu-Apraku and Fakorede, 2017). In Ghana, maize is cultivated on about 1.2 million ha per capita, annual consumption stands at 62 kg (Wongnaa and Awunyo-Vitor, 2019). Maize production is at the center of global food security and one of the most important cereal crops in human and animal diets worldwide. Maize is the most important cereal crop on the domestic market in Ghana. It accounts for more than one-quarter of calories consumed and about twice that of cassava, the most important crop (Adu *et al.,* 2018). Aside from providing nutrients for humans and animals, maize serves as the primary raw material for producing starch, oil, protein, alcoholic beverages, food sweeteners, and fuel (Chennakrishnan and Raja, 2012). Additionally, it is one of the most widely traded agricultural commodities amongst nations (Pechlaner and Otero, 2008).

The Ghana maize industry contributes significantly to the economy of Ghana, both upstream to the input industries and downstream to the processing industries (Amponsah *et al.,* 2021). Ghana's maize industry comprises producers or farmers, governmental organizations, and agribusinesses. Agribusinesses include trading companies, co-operatives, financial institutions. Moreover, the maize industry is divided into commercial and small-scale agriculture. Hence, it is an important crop from both the food security and income generation perspectives. It is worth noting that the industry is one of the most mechanized industries in Ghana, hence requires highly skilled labor relative to industries such as the table grape industry. With the maize industry included, primary agriculture contributes about 10% to formal employment (Wagh and Dongre, 2016). Moreover, the maize contribution towards foreign earnings has been growing (Adiaha, 2017). From 2012 to 2013, Ghana's maize foreign earnings grew significantly, and in real terms. This was on the back of increasing maize exports, from 81,681 tons to 100,848 tons. Already average maize output over 2017 to 2019 has been 40 percent higher than the average output achieved between 2013 and 2016 (Amponsah *et al.,* 2021). The Government of Ghana attributed this dramatic production response to the Planting for Food and Jobs (PFJ) policy. The uncertainty is whether the marketing of maize in Ghana can absorb this increment in the maize output without significantly impacting the market prices or the profitability of maize cultivation. This is set to change as Ghana's Planting for Food and Jobs (PFJ) initiative, launched in 2017, prioritizes maize seed and fertilizer distribution and encourages market participation by smallholders (Pauw, 2022).

2.2 Constraints in Maize Production

Despite this immense importance of maize in Ghana and Sub-Saharan Africa at large, its production is constrained by many factors. The most important abiotic constraints in Sub-Saharan Africa are low soil fertility and drought. Particular soils of the savanna, where maize potential is greatest, are low in fertility and soil organic matter (Kugbe *et al.,* 2019). Anthropogenic activities further aggravate these low fertility problems through continuous expansion of land for agriculture, human settlement, and other economic activities. Man has exposed the land to denudation agents, such as wind and water, resulting in increased soil erosion, reduced soil water retention, and increased emergence of persistent weeds (Martey, 2018). These different stresses inflict severe damage and contribute to yield losses to maize. Most soils in Ghana and across Sub-Saharan Africa are old and have been leached over a long period of time (Martey, 2018); those in humid (high rain forest and semi-deciduous forest (SDF) zones are an example. The soils are, therefore, characterized by low organic matter content, low water pH, and low nutrient buffer capacities, implying that most soils are physically, chemically, and biologically degraded. Continuous crop cultivation has also compounded the problem of soil fertility. In addition to that, traditional practices of bush burning and burning of crop residues have led to loss of organic matter from the soil (Martey, 2018). The loss of soil organic matter, reduces soil nutrients availability to the maize to facilitate yield losses. Besides that, the performance of mineral fertilizers added to the soil is enhanced with the presence of organic matter in the soil. Kihara *et al.* (2016a) investigated the response of crops to fertilizer and amendments and concluded that increasing soil carbon can improve response to fertilizers. The need to sustainably increase soil productivity to improve maize yield is warranted across all Agro-ecological zones of Ghana; this can be achieved through the application of external inputs of nutrients into the nutrient-poor soils. Sources of these external nutrient inputs can be organic and inorganic fertilizers or a combination of both.

2.3 Fertilizer Use and Yield Responses

Although the importance of inorganic fertilizer is clearly emphasized in national development plans, its adoption is still low in Ghana (Bayite-kasule, 2009). Average fertilizer use as of 2019 is about 20.9 kg ha^{-1}, slightly above the Sub-Saharan Africa average of about 10 kg ha^{-1} but much lower than the global average of about 118 kg ha^{-1} (Hill and Kirwan, 2015). Africa contains 25 percent of the world's arable land, yet represents less than 1 percent of global fertilizer consumption (Sakho-Jimbira and

Hathie, 2020; Morris, 2007). Fertilizer application rates are relatively low for all crops, but the rates average slightly higher on maize fields; application rates average around 14 kg/ha on maize fields, accounting for about 64 percent of total fertilizer use (Sogbedji, 2010; Minot and Benson, 2009). Several studies have suggested that large increases in fertilizer usage are necessary to correct the massive nutrient losses of much of the arable land in Sub-Saharan Africa (Ramankutty *et al.,* 2018; Bruce *et al.,* 2018; Henao and Baanante, 2006; Hill and Kirwan, 2015).

2.4 Fertilizer Yield Responses

According to Ichami *et al.* (2019), fertilizer response is the incremental crop yield due to the high vegetative growth it promotes. They stressed that fertilizer response is a useful concept for identifying responsive and non-responsive soils. Kihara *et al.* (2016a) divided non-responsive soils into two categories: (i) soils in which low crop yields are observed and where crops respond poorly to fertilizers unless other amendments are applied (e.g., organic matter application, lime), and (ii) soils with a high level of fertility in which crops do not respond to a nutrient application or soil amendments. They then arrived at three crop response categories that distinguish soils as responsive and non-responsive to fertilizer application (i.e., responsive, fertile non-responsive, and degraded non-responsive). Although factors causing non-responsiveness of the soils are not yet clearly understood, these could include macro- and micronutrient depletion, aluminum toxicity concerning soil acidification, and increased sensitivity to drought conditions (Ichami *et al.,* 2019). Kihara *et al.* (2016a) found that non-responsive soils had the lowest Zn, B, Cu, Mn, and sodium (Na). Many scholars (Chikowo *et al.,* 2014; Kihara *et al.,* 2016b; Brown *et al.,* 2017) have demonstrated that marked soil fertility variations exist within and between farms, both as inherent factors or as differential management.

2.5 Fertilizer Recommendation in Ghana

Rigorous work to generate fertilizer recommendations for Ghana was implemented from 1948 until 1970, when the government recommendation rate of 80-40-0 lb acre^{-1} NPK was arrived at for maize (Komakech *et al*., 2015). Wortmann *et al.* (2017), Tetteh *et al.* (2017) and other scholars have made great efforts in improving the previously developed fertilizer recommendations, and this has resulted in the current N-P_2O_5-K_2O rate of 90-60-60 + 1.7Zn kg ha^{-1} for the Forest Savannah Transition zone and 100-40-40 kg ha^{-1} for the Guinea Savannah zone for maize. The current fertilizer recommendations are intended to increase maize yield from an average of 1.8 t ha^{-1} to 5 t ha^{-1} (Hijbeek *et al.,* 2021). However, given the great variability in soils, the underlying factors of yield responses of these rates must be examined to further guide improvement in future recommendations. Otherwise, those recommendation rates can still be considered blanket fertilizer recommendations with limited relevance for heterogeneous smallholder farms. As indicated by Rusinamhodzi *et al.* (2013), targeted application of mineral fertilizers and manure according to soil type and past management of fields is imperative for improving crop yields and nutrient use efficiencies.

2.6 History of Biochar

Biochar, a carbonized solid by-product of bioenergy production through high temperature pyrolysis or degasification of organic material under low oxygen conditions, has garnered research attention in recent years (Gwenzi *et al.,* 2015). However, most of the research on biochar production and its applications has been conducted in the USA, Australia, South America, China and Europe. Literature on the agronomic impacts of biochar show enhanced soil fertility and crop productivity, especially where biochar was combined with fertilizers (Igalavithana *et al.,* 2015). Enhancing nutrient uptake and use efficiency is particularly important in Sub-Saharan Africa where most farmers cannot afford chemical fertilizers. Benefits from biochar amendments are expected to show readily in inherently infertile soils with low organic carbon. Research on biochar use in Africa is still in its infancy (Torres, 2011). Although some of the studies have been ongoing for several years, evidence on beneficial effects of biochar amendments is still inconclusive. A review by Ulyett *et al.* (2014) of studies on charcoal conducted in the 1980s and 1990s showed marked improvements in soil quality and crop productivity at low charcoal additions (0.5 t ha^{-1}). Recent research suggests it has the potential to be used as a soil conditioner and as a container substrate amendment in agriculture and horticulture, and have improved several soil and substrate physical, chemical, and biological properties.

2.7 The Effect of Biochar on Physical and Chemical Properties of Soils

Biochar has high total porosity, and it could both retain water in small pores and thus increase water holding capacity and assist water to infiltrate from the ground surface to the topsoil through the larger pores after heavy rain (Rasa *et al.,* 2018). Liu *et al.* (2016) indicated that biochar application could increase available water capacity by over 22 %. Tripura (2022) demonstrated that biochar application could increase available water capacity from 0.12 to 0.13 m^3. A possible main mechanism for yield improvement may be the increase of soil water holding capacity after biochar treatment (Atkinson, 2018). Moreover, the formation and stability of soil aggregates as a result of the application of biochar to the soil could increase the crop production and the prevention of soil degradation (Ding *et al.,* 2016). The capacity of soil aggregation increased ranging from 8 to 36 % after the application of rice husk biochar (Ding *et al.,* 2016). He also reported that the application of rice husk biochar application could increase soil pore structure parameters by 20 % and shear strength, as well as decrease soil swelling by 11.1 % (Ding *et al.,* 2016).

2.8 Factors Influencing Biochar Efficacy

Some factors are needed to be considered for the application of biochar into the soil. The improvement of nutrient availability is dependent on the increase of soil pH caused by biochar addition, especially P and K (Liu *et al.,* 2012). Tomczyk *et al.* (2020) and Nelissen *et al.* (2014) indicated that biochar with high volatile matter content, which produces at higher temperature, contributes to N immobilization and microbial activity reduction which could inhibit plant growth. Furthermore, different biochar application rates were recommended for various soils with different texture because of the difference of soils buffering capacity (Gul *et al.,* 2015). They indicated that the low application rate (1%) of Thai traditional kiln biochar made from *Eucalyptus camaldulensis* was appropriate for the coarse-textured soil, which had low buffering capacity. However, the higher rate (2 %) of biochar was recommended for fine textured soil, which had higher buffering capacity compared to coarse-textured soil. Moreover, Ulyett *et al.* (2014) reported that the effect of biochar on field capacity and available water capacity varied across different soil types, and these effects were modified slightly but significantly in relation to specific soil properties.

2.9 The Retention of Soil Nutrients by Biochar

Biochar is a carbon-rich product which has shown positive effect to increase carbon sequestration of soil, it reduces greenhouse gas emissions that finally improve soil physicochemical properties (such as improvement of water-holding capacity, cation exchange capacity and overall stability), it is also useful to enhance soil fertility (such as nutrients availability and retention) and also participate in soil nitrogen cycling (Bolan *et al.,* 2022). Biochar has been considered as not only a source of releasing nitrogen nutrients but also a good soil amendment which participates in soil nutrient cycling of agroecosystem directly or indirectly (Peng *et al.,* 2021). Additionally, biochar affects soil nitrogen migration and distribution by the interaction between its physicochemical properties and soil (Tomczyk *et al.,* 2020). Many studies have reported that the leaching losses of soil nitrogen was mainly composed of total nitrogen and nitrite nitrogen while the biochar application can obviously reduce the risk of soil nitrogen leaching losses (Borchard *et al.,* 2019; Jia *et al.,* 2021; Zhang *et al.,* 2021; Nguye *et al.,* 2020).

Wu *et al.* 2013 and Pokharel *et al.* 2018 reported significant reductions in cumulative N_2O-N emissions (i.e., 66% and 15%, respectively) when biochar was incubated with Chernozems from Alberta. In Saskatchewan, (Hangs *et al.,* 2016) found that net N_2O-N emissions from Black Chernozems (0–15 cm) were reduced by 66% and 59% when shrub willow (*Salix* spp.) biochar (20 Mg C ha^{-1}) was applied with or without urea-N, respectively. Ding *et al.* (2016) reported that N_2O emission approximately decreased by ranging from 60 to 90 % and NO emission approximately decreased by ranging from 30 to 90 % after biochars treatment, which were produced from willow, pine, and maize. Moreover, the cumulative N_2O-N emissions could be decreased by ranging from 53.9 to 83.5% for the biochars applications ranging from 1 to 20 %, respectively (Stewart *et al.,* 2012). Besides, when urea and fertilizers were applied, N_2O emissions were decreased in all biochar treatments compared to the control with an average of 53 % (from 618 to 295 μg N kg^{-1}) and 84 % (from 3356 to 529 μg N kg^{-1}), respectively (Ding *et al.,* 2016). These results demonstrated that the influence of biochar on nutrients' fixing cannot be neglected.

Furthermore, amending soils with biochar has been shown to temporarily reduce NO_3-N and NH_4-N availability through microbial (Bruun *et al.,* 2012) and abiotic pathways (Güereña *et al.,* 2013). Biochar has the potential to produce farm-based renewable energy in an eco-friendly way. Specifically, the quality of biochar depends on several factors, such as the type of soil and the raw material used for carbonization, the pyrolysis conditions, and the amount of biochar applied to the soil (Weber and Quicker, 2018). In addition, the biochar amendment to soil proved to be beneficial to improve soil quality and retain nutrients, thereby enhancing plant growth (Vida *et al.,* 2020). Since biochar contains organic matter and nutrients, its addition increased soil pH, electric conductivity (EC), organic carbon (C), total nitrogen (TN), available phosphorus (P), and the cation-exchange capacity (CEC) (Bayu *et al.,* 2016).

2.10 Response of Maize to Biochar Application

Lusiba *et al.* (2018) reported that the addition of biochar 2 t ha^{-1} and 4 t ha^{-1} increased the grain yield and improved water use efficiency of the maize crop. Coomes and Miltner (2017) conducted an experiment on charcoal site and adjacent fields and found out that there were significant differences between the charcoal and the adjacent fields grain and biomass yield of maize increased by 91% and 44%, respectively. Mekuria *et al.* (2013) reported that the enhancement of maize yield due to soil amendments ranged from 0.77 to 3.79 t ha^{-1} at Naphok and from 1.21 to 5.14 t ha^{-1}. Liu *et al.* (2016) mentioned that biochar amendment could enhance yields, and biochar from rice straw showed a more positive effect on the yield of corn, peanut, and winter wheat than corn stalk biochar. Gebremedhin *et al.* (2015) mentioned that biochar significantly increased grain and straw yields of wheat by 15.7% and 16.5%, respectively over the control.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The experiment was conducted on 4th January, 2022 at the experimental field of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), College of Agricultural Education, Mampong-Ashanti campus. Mampong-Ashanti can be located north of Kumasi within the transitional zone which is between the Guinea Savanna in the North and the rainforest region of the south. Mampong-Ashanti is at about 457.5M above sea level and located at latitude 07 04'N of the equator and longitude 01°, 24'W (Asante *et al.,* 2019).

3.2 Soil Type

The type of soil in Mampong-Ashanti is Savanna Ochrosol, which is derived from the Voltaian sandstone which occurs on the upper and middle slopes of the Catena. The soil according to local classification belongs to the Bediesi series which is well drained, red, friable, and permeable with moderate water holding capacity and contains moderate amount of organic matter. It is classified as chronic luvisol in the FAO/ UNESCO legend (Asiamah, 1998). The soil of the area is suitable for growing many vegetables such as carrots, pepper, commercial crops such as yam, cassava; cocoa; maize and plantain also do well on the soil. The soil can be tilled either by manual or by mechanical.

3.3 Vegetation

The vegetation cover of the area is the savanna type with a lot of grasses. Some of these grasses include nut grass, guinea grass, and elephant grass. There are also a number of weeds found in the area with Siam weed, Centrosema and milk weed being the most predominant ones.

3.4 Climatic Condition

Total rainfall for the minor and major cropping season of 2020 was 910 mm while the average relative humidity for the minor and major was 79%. The major rainy season starts from Mid-March and ends in July, with a short dry spell in August. The minor season also starts from September and ends in Mid - November. The highest average temperature was 36 °C in January and the lowest was 29 °C in July (Okyere *et al.,* 2020).

3.5 Experimental Design

The Randomized Complete Block Design (RCBD) was used with four (4) treatments and three (3) replications. The total experimental area was 12 m x 16 m, which was divided into three (3) equal blocks. Each block contained four (4) treatments plots. Each plot also measured 2 m x 4 m. The blocks were separated by 1.5 m wide path whilst the plots were 1 m apart. The treatments were randomly assigned to the various plots in each block.

The treatments were as follows.

Treatment 1 (T1)	Control (No soil amendment)
Treatment 2 (T2)	NPK (250 kg /ha)
Treatment 3 (T3)	NPK (125 kg/ ha) + 3 t/ ha Biochar
Treatment 4 (T4)	6 t/ ha Biochar

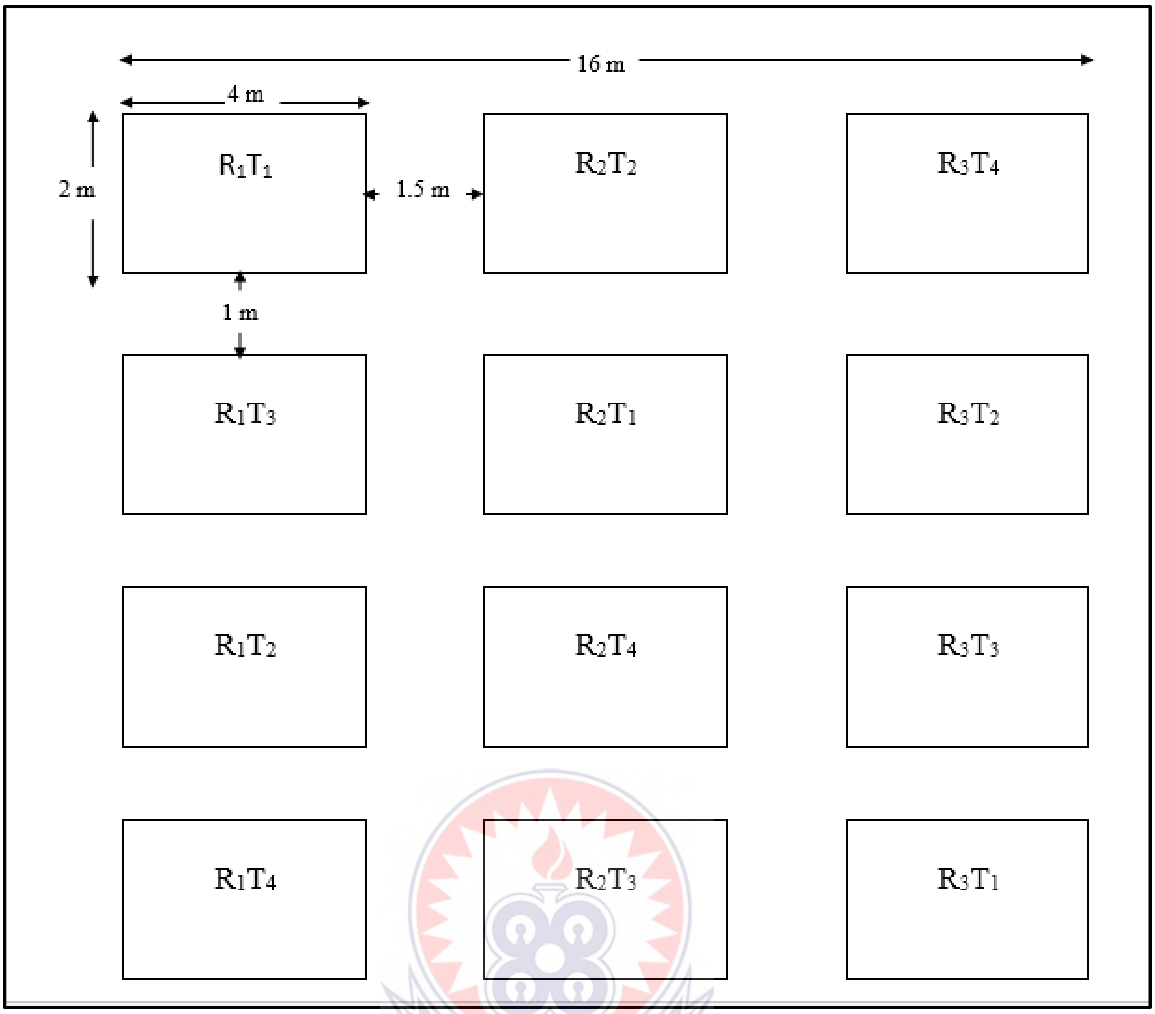

Figure 3. 1 Field Layout of Treatments

3.6 Preparation and Application of Biochar

Biochar of hard wood was bought from a local distributor and convey to the experimental site at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), College of Agricultural Education, Mampong-Ashanti campus. The biochar was manually crushed and sieved to 2 mm particle sizes.

The entire field was first watered to reduce the impact of the dust from the biochar and also to facilitate the application of the biochar. The application of the biochar to the plots that had to receive the biochar was done. 6 t/ ha of biochar was applied to the plots that received only biochar and 3 t/ ha of the biochar was applied to the plots that received both NPK fertilizer and biochar. It was spread uniformly with a rake and worked into the soil with a hoe at 10 cm deep. The field was left out for two hours after which planting was done.

3.7 Cultural Practices

3.7.1 Land Preparation

The experimental area was first sprayed with weedicide (Adom Glyphosate) at 300 ml/ 15 litre of water in a knapsack sprayer. The area was cleared from all the remaining weeds three days after the spraying of the weedicide. A day after weed clearance, the area was watered and tilled with hoe. The layout of the area with pegs, metre rule and garden lines took place after the tillage of the area.

3.7.2 Sowing

The maize variety (Omankwa) used in the experiment was obtained from CSIR- Crop Research Institute in Kwadaso in Kumasi. The sowing of the seeds took place two weeks after field clearance and tillage with cutlass, garden line and pegs. A space of 0.25 m was left from the boundary of each plot before both the first row and the inter rows plants were planted. Two seeds of Omankwa variety were planted at a planting distance of 0.75 m between rows and 0.25 m within rows. The seeds were planted at a depth of 3-5 cm into the soil. The two seeds planted per hill were later thinned to 1 plant per hill. Each plot had 3 rows with 14 plants per row so altogether 42 plants.

3.8 Fertilizer Application

Inorganic fertilizer, NPK 20:10:10 3S was applied at 250 kg ha^{-1} to the plots two weeks after planting. Hence, a plot that received only NPK and was measuring 8 m^2, a proportional amount of 200 g of NPK was applied. A proportional amount of 100 g of NPK was applied to the plot that received both NPK and biochar and measured the same 8 m^2. The NPK was applied through side dressing method 3 cm to the established seedlings.

3.9 Weeds Control

Weeding using hoe was done whenever weeds appeared.

3.10 Watering

The plants were irrigated because the time of planting was in the dry season and maize plants actually need a lot of water that time to ensure proper growth and development of the plants. The plants were irrigated twice per day. The watering holes was used and each plot was watered for five minutes anytime plants were irrigated. The same quantity of water was applied to each maize plant.

3.11 Pest and Disease Control

Fall armyworm was controlled using Attack insecticide (active ingredient is Emamectin Benzoate) at 25 ml/ 20 l water. Application was done when plants showed 3 – 6 leaves.

3.12 Harvesting

The maize on the field was harvested 95 days after planting when the ears were dry. Harvesting was done with cutlass. The maize was conveyed to the work station.

3.13 Sampling

The plants in the middle row of each plot were counted excluding the border plants which were the first and the last plants on the row. Pieces of paper were numbered up to 12 after the counting of the plants in the middle row. After that each plant in the middle row was represented by a number. The numbered papers were used to randomly select the four sampled plants for each plot. Data were taken on the sampled plants in each plot.

3.14 Data Collection

The following phonological data were taken in the experiment: germination percentage, days to 50% tasseling, days to 50% silking and days to 50% maturity. Moreso, data on growth and yield parameters were recorded. Data on the following growth parameters were taken in the experiment: plant stem girth, number of leaflets, leaf width, leaf length and plant height. The above data were taken three weeks after planting and at two weeks intervals. In the field experiment, four plants were selected in the net plot for collection of the following data: plant height (cm), plant stem girth, leaf width, leaf length, number of leaflets. For determination of yield parameters, four plants were selected and cob weight, cob length, cob diameter, 100 seed weight (g), number of rows per cob and number of grains per cob were measured.

3.15 Growth Parameters

3.15.1 Plant Girth

Data on plant girth was taken. The first data was taken three weeks after planting and subsequently every other week until plants were seven weeks. The measurement was done and recorded using venier calipers. The measurement was taken from the base of each of the sampled plants 4 cm above the ground level.

3.15.2 Leaf Number

The leaf number was recorded for each of the tagged plants in each plot three weeks after planting and subsequently every other week until plants were seven weeks. The average leaf number was expressed in number.

3.15.3 Leaf Width

The width of the leaves of the sampled plants were measured from the third week after planting and subsequently every other week using a tape measure.

3.15.4 Leaf Length

The length of the leaves of the sampled plants were measured from the third week after planting and subsequently every other week using a tape measure.

3.15.5 Plant Height

Data on plant height was taken. The first data was taken three weeks after planting and subsequently every other week. Plant height was measured from the ground level to the tip of the terminal leaf with a meter rule.

3.16 Yield parameters

3.16.1 Cob Weight

The dehusked cobs of all the sampled plants on each treatment was bagged together and weighed. The cobs mean weight of each treatment was computed and expressed as mean cob weight.

3.16.2 Cob Length

The length of the dehusked cobs of all the sampled plants on each treatment was measured and recorded using meter rule. The cobs mean length of each treatment was computed and expressed as mean cob length in centimeter (cm).

3.16.3 Cob Diameter

The diameter of the dehusked cobs of all the sampled plants on each treatment was measured by using caliper at basal portion and the average cob diameter was expressed in centimeter (cm).

3.16.4 Seed Weight

Weight of 100 seeds was also recorded for each treatment. The seed weight was computed from field weight (kg/m^2), and was adjusted to 15% moisture content and 80% shelling percentage (Salami *et al.*, 2003).

3.17 Data Analysis

The data collected on some growth parameters and yield parameters were grouped through their means, coefficient of variation and the least significant difference. The data were subjected to analysis of variance using GenStat software package. The means were separated using Least Significant Difference (LSD) at 5 % probability level.

CHAPTER FOUR

4.0 RESULTS

4.1 Growth Parameters as influenced by the Treatments

4.1.1 Plant girth

The effect of NPK and biochar on maize plant girth (cm) at different weeks after planting is described in Table 4.1. It was clear that NPK+Biochar treatment plots recorded the highest plant girth in all the weeks. It was also clear that biochar alone recorded the least plant girth in all the weeks. The plants on the control plots were able to perform better than the plants grown on the biochar amended plots in all the weeks. NPK treated maize plants also recorded the third highest plant girth at 3 WAP and 7WAP but recorded the highest plant girth value of 1.44 cm at 5 WAP and this value was at par with the value recorded by the combination of biochar and NPK treatments. No significant difference (P>0.05) was observed among the treatments. However, it was clear that there is a noticeable difference in plant girth with NPK+Biochar treatment plants compared to sole biochar treatment plants. While NPK+Biochar treatment plants recorded the highest plant girth at 3 WAP, 5 WAP and 7 WAP, NPK treatment plants and the plants from the control plots recorded the second and third highest plant girth respectively at 3 WAP, 5 WAP and 7 WAP. There was the same trend in plant girth in all the weeks. Statistical analysis shows that the organic soil amendment (biochar) in combination with NPK affected plant girth as shown in Table 4.1.

Table 4.1 Influence of Treatment Combinations on Plant Girth

	Plant Girth		
Treatment	3 WAP	5 WAP	7 WAP
Control	0.95a	1.40a	1.42a
Biochar	0.91a	1.24a	1.29a
NPK	0.98a	1.44a	1.48a
NPK+Biochar	1.10a	1.44a	1.51a
LSD	0.46	0.48	0.58
CV	14.7	16.4	15.4

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV = coefficient of variation, LSD = least significant difference at 5% WAP = Weeks after planting, T = Treatment, NPK = Nitrogen, Phosphorus, Potassium.

4.1.2 Number of Leaves

Results from the number of leaves produced per plant as shown in Figure 4.1 indicated that NPK+Biochar treatment plants recorded the second highest value of 5.17 at 3 WAP after NPK treatment plants that recorded 5.33 but recorded the highest number of leaves at 5 WAP and 7 WAP. The plants grown on the control plots performed better than plants grown on biochar amended plots during 3 WAP and 7 WAP but the performance was far better at 5 WAP than both NPK and sole biochar treatment plants. The biochar amended plants recorded the least number of leaves over the period. The was no significant difference (P>0.05) among all the treatments in the weeks as indicated in Table 4.1. The general trend was that the number of leaves during the period increased exponentially within the growing season with the plants from the control plots recording the lowest number of leaves during the entire season. Statistical analysis shown that the organic soil amendment (biochar) in combination with NPK affected the number of leaves.

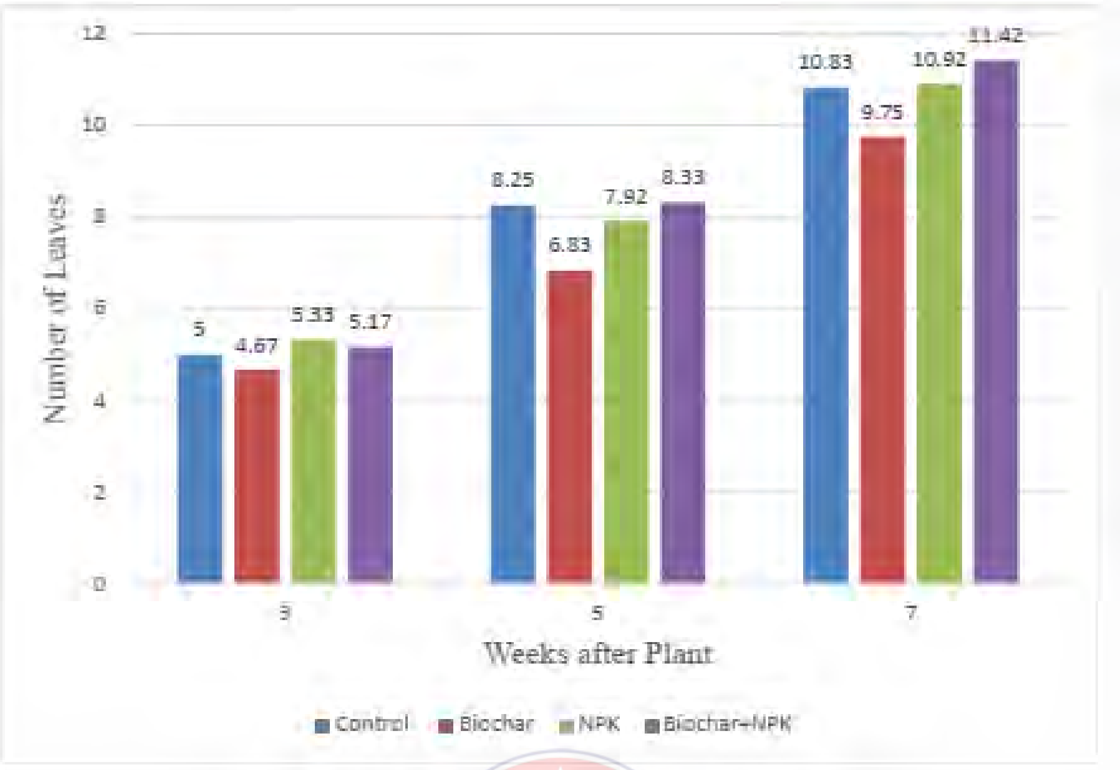

Figure 4.1 Number of Leaves as influenced by treatments

4.1.3 Leaf Width

Result regarding leaf width of maize is reported in Table 4.2. Integrated application of NPK and biochar and sole NPK treatment plants recorded the highest and second highest respectively for leaf width in the period of data collection. At 3 WAP, biochar treatment plants recorded the third highest leaf width (3.29 cm) over the plants from the control plots that recorded the least leaf width (3.07 cm). It can be observed from Figure 4.3 that plants from amended plots performed better than plants from control plots at 3 WAP. However, at 5 WAP and 7 WAP, the maize plants without treatment recorded 6.82 cm and 7.60 cm respectively as third highest for leaf width as against 6.42 cm and 7.08 cm that was recorded by biochar treatment plants as the least values for leaf width. Leaf width of maize was not significantly (P>0.05) affected by various N sources (organic and inorganic) and their combinations. It can be observed from Table 4.2 that leaf width enlarged as the number of weeks increased among all the treatments.

Table 4.2 Influence of Treatment Combinations on Leaf Width

	Leaf Width		
Treatment	3 WAP	5 WAP	7 WAP
Control	3.07a	6.82a	7.60a
Biochar	3.29a	6.42a	7.08a
NPK	3.46a	6.94a	7.68a
NPK+Biochar	3.51a	7.15a	7.70a
LSD	1.31	2.76	1.84
CV	20.9	21.5	13.0

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV = coefficient of variation, LSD = least significant difference at 5%, WAP = Weeks after planting, T = Treatment, NPK = Nitrogen, Phosphorus, Potassium.

4.1.4 Leaf Length

Result of the leaf length is indicated in Figure 4.2. NPK treatment plants recorded the longest leaf length at 3 WAP. This was followed by the plants that received the combination of NPK and biochar. The plants grown on the control plots recorded longer leaf length than the plants that were grown on the sole biochar amended plots. Meanwhile, at 5 WAP the plants that received NPK and biochar combination recorded the longest leaf length and was followed by the plants that received NPK treatment. The third longest leaf length was observed in the plants from the plots that received biochar alone. The results also indicated that at 7 WAP NPK+Biochar combination still recorded the longest leaf length. The maize plants without treatment surprisingly recorded the second longest leaf length at 7 WAP. The leaf length recorded by the plants that received no treatment was at par with the leaf length recorded by the plants that received NPK treatment. The short leaf length was recorded by the sole biochar treatment plants. The results show that the plants grown on the control plots performed better than the plants that received sole biochar treatment. No significant difference (P>0.05) was observed among the treatments in all the weeks data were collected (Figure 4.2). The trend in the growth of leaf length observed was that the leaf length increased as the plant grew.

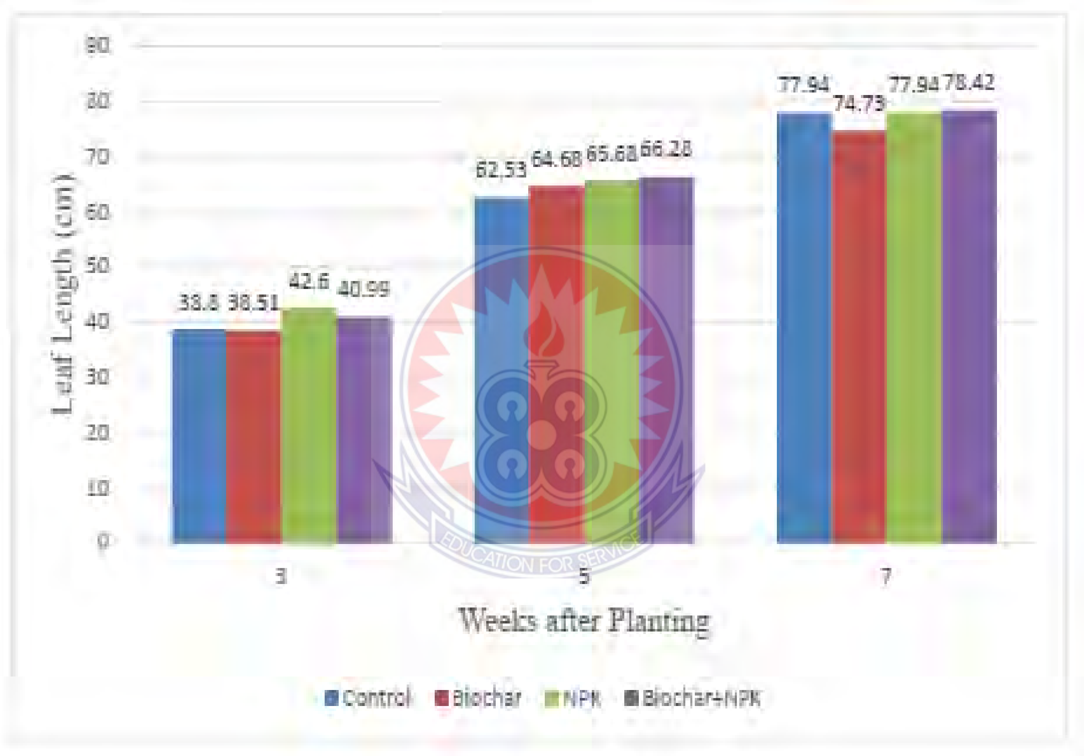

Figure 4.2 Leaf Length as influenced by treatments

4.1.5 Plant Height

Result of plant height of maize in the different treatments and their interactive effect are presented in Figure 4.3. At 3 WAP, 5 WAP and 7 WAP NPK+Biochar treatment plants recorded the tallest plant height (12.26 cm), (39.58 cm) and (98.54 cm) in that order. NPK treatment plants also recorded the second tallest plant height (11.68 cm), (38.46

cm) and (88.83 cm) at 3 WAP, 5 WAP and 7 WAP in that order. Plants grown on the control plots recorded the shortest plant height (9.83 cm), (37.27 cm) and (75.50 cm) at 3 WAP, 5 WAP and 7 WAP in that order. The plant heights recorded at 3 WAP, 5 WAP and 7 WAP produced no significant variation (P>0.05) among all the treatments as shown in Figure 4.3. Statistical analysis shows that the organic soil amendment (biochar) in combination with NPK affected plants height. All treatments increased their corresponding plant heights with time peaking at 7 WAP. The rate of growth was rapid during the vegetative phase of the maize plant up to 7 WAP after which growth slowed down as the reproductive phase was initiated.

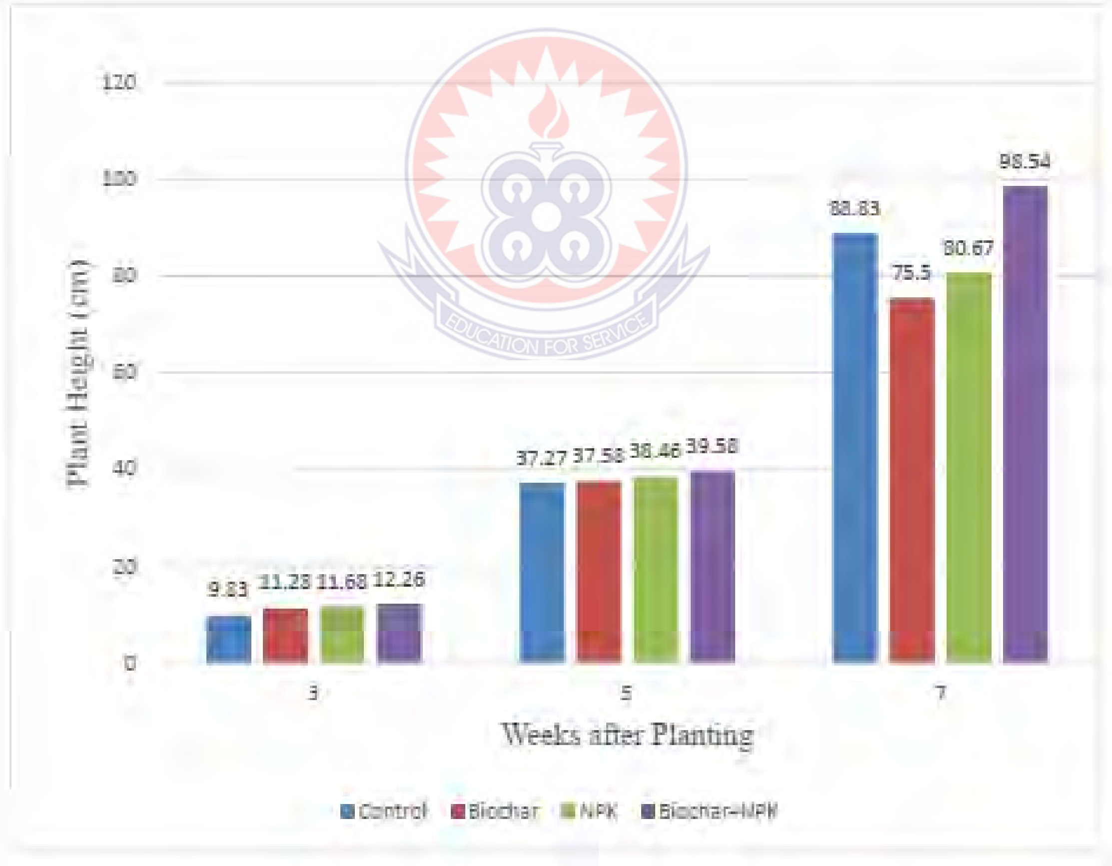

Figure 4.3 Plant Height as influence by treatments

4.2 Phenological parameters

4.2.1 Germination %

The germination percentage of maize seeds on the 7th day after planting in the different treatment plots are reported in Table 4.3. At one (1) week after planting, data on germination percentage of the seeds that have emerged were taken. Even though the germination percentage was very high, the highest germination percentage was recorded by plants that received NPK+Biochar and sole biochar and the least recorded by the plants that received NPK. The plants from the control plots recorded higher germination percentage than the plants treated with NPK. At one (1) week after planting there was no significant difference (P>0.05) among the germination percentage on the control, sole biochar and NPK+Biochar treatments plots (Table 4.3). However, the effect of control, biochar and NPK+Biochar treatments was significantly (P<0.05) higher than the sole NPK application. The highest germination percentage (96.97%) was recorded by plants that received NPK+Biochar and sole biochar. The plants on the control plot recorded (96.67%) as the third highest germination percentage while plants that were treated with NPK had (83.13%) germination recorded as the least germination percentage.

4.2.2 Days to 50% tasseling

Result of the number of days to 50% tasseling of maize as affected by NPK+Biochar, NPK, biochar treatments and the control are presented in Table 4.3. The interval between the days to 50% tasseling was close among the treatments. Plants that tasseled early happened to be those that were planted on biochar amended plots. Late tasseling plants were recorded from the control plots. The early tasseling plants on the biochar amended plots used 53 days to obtain 50% tasseling. This was followed by plants that received NPK+Biochar treatment that used 53.33 days to obtain 50% tasseling. Plants that were grown on the NPK treatment plots also obtained days to 50% tasseling at 53.67 days after planting. The plants that were late to reach days to 50% tasseling were recorded from the control plots at 55.0 days after planting. Statistical analysis of the data indicated no significant difference (P>0.05) in the number of days to 50% tasseling among all the treatments (Table 4.3).

4.2.3 Days to 50% silking

From the results in Table 4.3, it can be observed that plants that received NPK+Biochar treatment reached days to 50% silking earlier recording (56.33) days. This was followed by plants that received sole biochar treatment that reached days to 50% silking at 57.33 days. Plants grown on the NPK treatment plots recorded days to 50% silking at 53.67 days. The late silking plants were recorded from the control plots that used 58.67 days after planting to reach days to 50% silking. Statistical analysis of the data indicated no significant difference (P>0.05) in the number of days to 50% silking among all the treatments as shown in Table 4.3.

4.2.4 Days to 50% Maturity

Result regarding the number of days to maturity of maize as affected by NPK+Biochar, NPK, biochar treatments and control are presented in Table 4.3. It can be observed that plants that received NPK+Biochar treatment reached days to 50% maturity earlier recording (82.0) days. This was followed by plants that received NPK treatment plots that reached days to 50% maturity at 88 days. Plants grown on the sole biochar treatment plots recorded 88.67 days to reach 50% maturity. at 53.67 days. The late maturing plants from the control plots used 89 days to reach days to 50% maturity.

Statistical analysis of the data indicated that the days for which plants that received NPK+Biochar treatment took to reach 50% maturity was significantly (P<0.05) lesser than the days plants that received sole biochar treatment, NPK treatment and no treatment (control) took to reach 50% maturity. However, no significant variation (P>0.05) was observed between the biochar and the NPK treatment plots regarding days to 50% maturity (Table 4.3). NPK+Biochar treatment plants took lesser days (82) to reach days to 50% maturity. The plants grown on the control plots took more days (89) to reach 50% maturity.

Table 4.3 Influence of Treatments on Germination %, Days to 50% tasseling, Days to 50% silking, Days to 50% maturity

Treatment	Germination %	Days to 50% tasseling	Days to 50% silking	Days to 50% maturity
Control	96.67b	55.00a	58.67a	89.00b
Biochar	96.97b	53.00a	57.33a	88.67b
NPK	88.13a	53.67a	57.67a	88.00b
NPK+Biochar	96.97b	53.33a	56.33a	82.00a
LSD	0.63	5.21	5.68	1.44
CV (%)	5.7	5.2	5.2	0.9

Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV = coefficient of variation, LSD = least significant difference at 5%, WAP = Weeks after planting, T = Treatment, NPK = Nitrogen, Phosphorus, Potassium.

4.3 Effect of Biochar and NPK on Yield and Yield Parameters

4.3.1 Cob Weight

The result of the cob weight analysis showed that the weight of maize cobs was influenced by the different treatments applied. NPK+Biochar treatment plants produced the heaviest cob weight (175.6 g/cob), whereas the biochar treatment plants produced the lightest cob weight (140.2 g/cob). The plants from the control plots recorded heavier cob weight of 163 g than the NPK treatment plants that recorded 140.4 g and the biochar treatment plots that recorded 140.2 g. There was no significant difference ($P>0.05$) among the treatments on cob weight as shown in Table 4.4. However, the gap between cob weight from the NPK+Biochar treatment plants and sole biochar treatment plants which is 35.4 g is high.

4.3.2 Cob Length

Result regarding cob length is indicated in Table 4.4. NPK+Biochar treatment plants recorded the longest cob length of 15.83 cm. This was followed by the plants that received no treatment with a cob length of 15.17 cm. The third longest cob length of 14.01 cm was recorded by the NPK treatment plants. The plants that recorded short cob length were the ones biochar was applied to. It is clear from the result that plants from the control plots recorded longer cob length than the plants grown on the NPK treatment plots and the biochar treatment plots. Cob length recorded in case of plants from the control plots was not significantly different ($P>0.05$) from the plants grown on NPK and Biochar treatment plots. However, the effect of cob length of plants from NPK+Biochar treatment plants was significantly ($p<0.05$) higher than the cob length of plants from sole biochar and NPK treatment plots.

4.3.3 Cob Diameter

The results in Table 4.4 indicated cob diameter. Thickest cob diameter (4.45 cm) was observed in NPK+Biochar treatment plants. Small cob diameter (4.17 cm) was also observed in plants that received NPK application. Thick cob diameter (4.26 cm) was observed in plants that received sole biochar application which was at par with the plants that receive no treatment (4.26 cm). This means that plants that were grown on the control plots had thicker cob diameter compared to the plants that were grown on NPK amended plots. The results indicated no significant difference (P>0.05) in cob diameter among all the treatments.

4.3.4 Hundred Seeds Weight

Results on hundred seeds weight is shown in Table 4.4. The results indicated that NPK+Biochar treatment plants recorded the heaviest hundred seeds weight (1.28 g). This was followed by NPK treatment plants that recorded (1.24 g) for 100 seeds weight. Sole biochar treatment plants recorded (1.06 g) as third highest 100 seeds weight. The plants that received no treatment recorded the lightest 100 seeds weight (1.02 g). NPK+Biochar amended plants had shown significantly heavier 100 seeds weight than the control and biochar treatment plants. Hundred seeds weight for NPK+Biochar was significantly higher (P>0.05) than the control treatment, but insignificantly different from NPK treatment plants.

4.3.5 Rows per cob

Table 4.4 indicates number of rows per cob. Plants from the plots that received NPK+Biochar incorporation recorded the highest number of rows per cob (14.00) of maize which was at par with the plants grown on the control plots (13.50). Least number of rows per cob (13.10) was observed in NPK treatment plants which was also at par with biochar treatment plants (13.17). The control plots recorded plants with higher number of rows per cob than the NPK treatment plants and sole biochar treatment plants. Number of rows per cob recorded no significant difference (P>0.05) among all the treatments.

4.3.6 Grains per cob

Result of grains per cob of maize is presented in Table 4.4. NPK+Biochar treatment plants recorded the highest number of grains (438.2) per cob. Plants grown on the NPK, Biochar and control plots recorded 419.5, 355.5 and 353.7 grains per cob in that order. NPK+Biochar application increased the number of maize grains per cob. The number of grains per cob (353.7) of maize at the experimental site was quite low as observed in the plants from the control plots. When biochar and NPK were applied together, there was also an increase in the number of grains in the cobs. No Significant variation (P>0.05) in grains per cob of maize among the treatments was observed.

Table 4.4 Influence of Biochar and NPK on Cob Weight, Cob Length, Cob Diameter, 100 Seeds Weight, Rows per Cob, Grains per Cob

Treatment	Cob Weight (g)	Cob Length (cm)	Cob Diameter (mm)	100 Seed Weight (g)	Rows per Cob	Grains per Cob
Control	163.4a	15.17a	4.26a	1.02b	13.50a	353.7a
Biochar	140.2a	13.55b	4.26a	1.06a	13.17a	355.5a
NPK	140.4a	14.01c	4.17a	1.24a	13.10a	419.5a
NPK+Biochar	175.6a	15.83a	4.45a	1.28a	14.00a	438.2a
LSD	62.00	1.75	0.55	0.18	2.47	94.30
CV (%)	21.3	6.3	6.8	4.5	7.7	14.5

*Means followed by or sharing the same letters within a column are not significantly different at 5% level of significance; CV = coefficient of variation, LSD = least significant difference at 5%, T = Treatment, NPK = Nitrogen, Phosphorus, Potassium***.**

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Treatments on Growth Parameters

The effect of NPK and biochar on maize plant girth (cm) at different weeks after planting is described in Table 4.1. The treatment plants where biochar in combination with NPK was applied recorded bigger stem girth than all the other treatments and this might be as a result of the biochar improving the soil properties as well as the NPK supplying nutrient to the soil for plant growth. This is in line with the study by Brown *et al.* (2017) who reported that the addition of biochar and N fertilizer treatments increased the plant height, number of tillers and stem diameter in rice in comparison to the control.

Results regarding the number of leaves produced per plant showed that maize plants that received NPK and biochar combination gave the highest number of leaves as compared to the biochar amended plants and this might be due to the high nitrogen and presence of exchangeable cations in the organic amendments. According to Singh *et al.* (2014), adequate amounts of nitrogen may be obtained from reasonable amounts of organic matter applied to the soil and it is directly responsible for the vegetative growth of plants. The number of leaves per plant is relevant to canopy development and closure, which is significant for the interception of solar radiation, dry matter accumulation and partitioning. This is similar to studies done by Zucco *et al.* (2015) who found out that, higher rates of application of organic amendments produced more leaves. Statistical analysis shows that the organic soil amendment (biochar) in combination with NPK affected the number of leaves produced by the maize plants on NPK+Biochar treatment plots compared to the plants that received sole biochar treatment. The number of leaves produced is directly linked with the plant ability to absorb essential nutrients for vegetative growth and development and might also be related to plant density in response to competition for available space. This agrees with the findings of Mendieta-Araica *et al.* (2013) that for most crops, plant density has a major influence on biomass. Leaf width results obtained in Table 4.2 indicated that maize plants treated with NPK+Biochar produced the longest leaf width. However, maize plants obtained from biochar amended plots had the least leaf width and this finding is not different from Beesigamukama *et al.* (2021) who investigated and came out with the findings that limited mineralization of organic N found in the biochar makes it a slow release N fertilizer.

Results regarding leaf length of maize plants as indicated in Figure 4.2 shown that treated with NPK+Biochar and sole NPK recorded the longest leaf length in all the weeks. These results could be attributed to positive effect of NPK on vigorous vegetative growth (Gurmu and Mintesnot, 2020). Biochar treatment plants recorded the shortest leaf length during the third and seventh week after planting and this results could be due to delay in releasing nutrients by biochar into the soil. Beesigamukama *et al.* (2021) in their investigation came out with the findings that limited mineralization of organic N found in the biochar makes it a slow release of N fertilizer. The results of the plant height revealed that plants from the plots treated with NPK+Biochar showed the tallest plant height. The tallest plants observed in the NPK+Biochar treatment plots could be as a result of combined effects of the biochar improving the physical soil conditions and NPK fertilizer also improving the nutrient status of the soil. Arif *et al.* (2012) stated that combined application of inorganic fertilizer might have positively affected maize since biochar is found to improve soil physical properties and synthetic fertilizer found to increase mineralization and diorites the soil productivity. Short stature plants were observed in the control plots and this could also be as result of the low nutrient in the soil to support plant growth and this findings is in support of the findings of Khan *et al.* (2009).

5.2 Influence of Biochar and NPK on Phenological Parameters of Maize

The days to germination of maize seeds was affected by treatments applied. The maize plants treated with biochar, combination of NPK and biochar recorded significant changes in the germination percentage within the first 7 days compared to the sole NPK treated plants which had low percentage germination. This high germination percentage obtained from the plants that received the combination of biochar and NPK and sole biochar might also be due to the high soil organic matter and nutrients (Huang *et al.,* 2017). The lower percentage crop establishment in NPK treatment plots might be due to low viability of seed (Finch-Savage and Bassel, 2016).

The number of days to tasseling of maize as affected by NPK+Biochar, Biochar, NPK and control are presented in Table 4.3. The least days to 50% tasseling (53) was recorded by plants on biochar amended plots. Possible explanation for the least days to 50% tasseling in biochar amendments plants include, the effect of biochar on soil physio-chemical properties like enhance water holding capacity, increased cation exchange capacity (CEC), and providing a medium for adsorption of plant nutrients and improved conditions for soil micro-organisms (Sohi *et al.,* 2009). Biochar efficiently adsorbs ammonia (NH_3) (Sun *et al.,* 2018 and Dawar *et al.,* 2021) and acts as a binder for ammonia in soil, therefore having the potential to decrease ammonia volatilization from soil surfaces. The plants from the control plots recorded the highest days to 50% tasseling and this might be due to low nutrient in the soil. Application of biochar reduced days to tassel appearance in maize (Arif *et al.,* 2012). The control plots recorded the highest days to 50% tasseling and this might be due to low nutrient in the soil (Rafiq *et al.,* 2010). In this study, the plants from the plots amended with NPK+Biochar recorded the least number of days to 50% silking as shown in Table 4.3. The least days to silking recorded by NPK+Biochar treatment plants is because combination of chemical fertilizer with organic material (biochar) has shown great potential for SOC sequestration in paddy soils (Laghari *et al.,* 2016), especially soils with low levels of organic matter (Kizito *et al.,* 2019). Plants from control plots recorded the longest days to 50% silking and this might be as a result of insufficient nutrients in the soil (Seyed and Namvar, 2016).

On days to 50% maturity as shown in Table 4.3, the results indicated that the days for which NPK+Biochar took to reach 50% maturity was lesser than the days sole biochar, NPK and Control treatments plants took to reach 50% maturity. The least days taken by the NPK+Biochar treatment plants to reach 50% maturity can be ascribed to Organic soil management which can substantially improve soil structure (Wang *et al.,* 2021), help retain C in the surface soil, and increase crop yields in rice-rice crop systems (Bhattacharyya *et al.,* 2015). It took plants grown on the control plots more days to reach 50% maturity (89) and this might be attributed to low plant nutrient in the soil to support plant growth and development (Gurmu and Mintesnot, 2020).

5.3 Influence of Treatments on Yield and Yield components of Maize

5.3.1 Cob Weight

The cob weight analysis results (Table 4.4) showed that the weight of maize cobs was influenced by the different treatments applied. NPK+Biochar treatment plants produced the heaviest cob weight (175.6 g/cob), whereas the biochar treatment plants produced the lightest (140.2 g/cob). The heaviest cob weight observed by NPK+Biochar treatment plants could be ascribed to the fact that the added biochar and NPK increased the supply and availability of plant nutrients in the soil. This results is in line with Arif *et al.* (2012) who reported that the combine application of NPK and organic amendments are more effective, than the sole application of either organic or inorganic amendments. In other studies, increased yield was also observed when biochar and inorganic fertilizers were applied together (Huang *et al.,* 017; Mete *et al.,* 2015; Kalu *et al.,* 2021; Sänger *et al.,* 2017).

Literature on the agronomic impacts of biochar show enhanced soil fertility and crop productivity, especially where biochar was combined with nitrogen fertilizers (Igalavithana *et al.,* 2015). These results are in accordance with Abukari (2018) who suggested that timely availability of Nitrogen could be insured and corn productivity can be positively increased by combined use of mineral Nitrogen and biochar. These results are in line with Ali *et al.* (2011) and Zhou *et al.* (2019) who found that corn yield was 35% increased by integrated N management. The light cob weight observed in biochar treatment plants may also depend on a lot of factors such as climate, type of soil and biochar ageing effect. Schulz and Glaser (2012) reported decreased plant growth during the second growing season compared to the first growing season after biochar application. In a temperate maize-based production system on fertilized soils in America, Güereña *et al.* (2013) found no effect of biochar addition on N concentrations and total N uptake in maize. With significant interaction effects of NPK+Biochar on cob length, it can be inferred that the application of NPK+Biochar affected cob length differently as compared to the sole NPK and sole biochar. In a work done by Kätterer *et al.* (2019), they reported that cob length increased when Nitrogen was applied in integration with biochar as compared to sole Nitrogen application. Combined application of biochar and inorganic fertilizer might have positively affected maize cob length characteristics due to incorporation of the biochar that improved soil physical properties as the use of synthetic fertilizer increases mineralization and diorites of the soil productivity (Arif *et al.,* 2012). The short cob length of biochar treatment plants may also depend on a lot of factors such as climate, type of soil and biochar ageing effect. Schulz and Glaser (2012) reported decreased plant growth during the second growing season compared to the first growing season after biochar application.

Similarly, Karer *et al.* (2013) also reported negative effect of biochar on wheat and maize grain yield after application of 72 t/ha of biochar in the temperate region. The study revealed that maize plants grown on plots that received NPK and biochar combination had thickest cob diameter than the maize plants that received the other treatments. Kätterer *et al.* (2019) reported that cob diameter increased when nitrogen was applied in integration with biochar. Small cob diameter (4.17 cm) was observed in plants where NPK was applied. Application of NPK+Biochar resulted in the thickest cob diameter as compared to other treatments and this might be attributed to longer and wider leaf area of the plants produced by the combined treatment for maximum photosynthetic activities and this conform to the report by Fru *et al.* (2017) when they conducted a study on cob diameter. Again, the thickest cob diameter obtained by NPK+Biochar treatment plants might also be due to effective release of nutrients from inorganic fertilizer and biochar to the soil and subsequent plant nutrient. It might also be due to the combined effects of Biochar and NPK which have resulted in high inherent nutrients soil which promoted broader grain size and increased meristematic activities that favoured the enlargement of cob. Arif *et al.* (2012) reported that cob diameter increased when Nitrogen was applied in integration with biochar. NPK treatment plants recorded small cob diameter and this might be as a result of NPK supply below the optimal dosage. Increased nitrogen uptake by plants would support a lot of assimilation to the cob so that the number of grains and the weight of the cob increased (Sofia *et al.,* 2019).

In terms of hundred seeds weight, results showed that maize plants from the treatments combination plots obtained a significantly heavier hundred seeds weight than the control plots. This result implied that application of NPK and organic amendments combination had contributed to a more positive effect on grain filling. Liao *et al.* (2020) showed that under high N supply conditions, both grain number and grain weight of the pollen donor and receptor hybrids increased. Similarly, increasing N application up to the maximum tested rate of 200 kg N ha^{-1} or 314 kg N ha^{-1} (Liu *et al.,* 2011) resulted in the increase of both grain number and grain weight. The lower N level in the control plots resulted in lighter grain weight due to less available N for the optimum plant growth (Khan *et al.,* 2009) and formation of assimilates for healthy grains.

The increase in yield as a result of the number of grains per cob recorded by the maize plants that received the NPK and biochar organic combinations might have been due to the improvement of the physical structure of the soil and the nutrients supplied as stated by Dennis *et al.* (2014) and Frempong *et al.* (2010). In other studies, increased yield was also observed when biochar and inorganic fertilizers were applied together (Schmidt *et al.,* 2017; Kalu *et al.,* 2021; Mete *et al.,* 2015). According to Kätterer *et al.* (2019), there is a positive effect when biochar is applied along with NPK fertilizer. Similarly, current study cleared that the use of biochar with fertilizer increased the nitrogen concentration in shoot and grain than sole application of biochar. Other studies have shown that the use of biochar stimulates plant growth and increases fertilizer use efficiency, especially when biochar is combined with fertilizer (Schulz and Glaser, 2012; Liao *et al.,* 2020; Shi *et al.,* 2020).

The highest number of grains recorded by NPK+Biochar treatment plants may be due to increase in nutrient supply to the crops. In addition, the soil at the experimental site has low nutrients due to continuous usage of the site for growing crops by other researchers and this might have resulted to the least recorded grains per cob from the plants grown on the control plots. However, NPK+Biochar amended plots might have strongly benefited from the addition of biochar, which has been widely noted to improve hydrophysical properties and crop growth environment in similar soil conditions (Igaz *et al.,* 2018; Ndor *et al.,* 2015; Oladele *et al.,* 2019). The observation of highest relative effect of biochar for infertile soils is in line with the results of a meta-analysis on the effects of inorganic fertilizer, biochar and inorganic fertilizer + biochar on crop yield (Peng *et al.,* 2021). This development could be attributed to the improvement in soil nutrients, nutrient use efficiency, cation exchange capacity, soil structure, water-holding capacity and decreased soil acidity as a consequence of biochar addition (Oladele *et al.,* 2019; Igaz *et al.,* 2018; Ndor *et al.,* 2015).

Results obtained from the number of rows per cob proved that the plots where NPK+Biochar was incorporated into the soil produced plants with the highest number of rows per cob (14.00) than the maize plants from the plots where NPK was applied and had the lowest number of rows per cob (13.10). The highest number of rows per cob obtained from plants in biochar amended with NPK plots could be attributed to improved uptake of N by maize through enhancing the organic matter decomposition-mineralization process, or indirectly maize root development. The results of this study conform to the findings of Arif *et al*. (2012) who reported that soil physio-chemical properties could be improve and corn yield can be increased by the application of different organic matters in combination with commercial nitrogenous fertilizers. Nutrient availability from the NPK+Biochar treatment plots resulting in high leaf surface area providing more availability of assimilates according to Arif *et al.* (2012) and Nurhayati (2017) might have improved grain rows and number of grain rows per cob. NPK treatment plants recorded the least number of rows per cob and this might be as a result of inadequate supply of NPK to the soil to provide the plants with the needed nutrients. Increased nitrogen uptake by plants would support a lot of assimilation to the cob so that the number of grains and grains row of the cob increased (Akram *et al.,* 2010).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The experiment proved that soil organic amendment such as biochar affects both soil physical and chemical properties and render the soil environment conducive for crop growth which affect the growth of maize plant. Findings from the study revealed that the combination of biochar with NPK fertilizers increased maize growth parameters (stem girth, number of leaves, leaf width, leaf length and plant height). Maize yield parameters, namely cob weight, number of rows per cob and number of grains per cob also increased considerably on the plants that received biochar and NPK combination. Additionally, application of biochar in combination with NPK fertilizers shown significant increase in cob length, cob diameter and 100 seed weight. The greater yield of maize recorded on NPK+Biochar amended soils was attributed to the combined effects of the biochar improving the physical soil conditions and NPK fertilizer also improving the nutrient status of the soil.

Not only did the combination of biochar and NPK fertilizers increased growth and yield parameters but also increased phenological parameters such as germination percentage, days to 50% tasseling, days to 50% silking and days to 50% maturity over the other treatments. In essence, this study has demonstrated that the application of combined biochar and NPK fertilizer is not only ecologically prudent, but economically viable and a practicable alternative to current farmers’ practice of cultivating maize in Ghana. For this reason, the combined use of NPK and biochar is a suitable practice to improve the fertility status of the soil. According to results reported in this study, it suggests that the integrated use of NPK and biochar in the cultivation of maize improves soil fertility status and boost maize yield and therefore is recommended to farmers in Ghana to improve their soil fertility and increase maize grain yield and also maximize profit.

6.2 Recommendations

1. It is recommended that 3 tons/ha biochar combined with 125 kg/ ha NPK should be applied by farmers to improve the soil fertility on infertile soil to achieve high yielding results.
2. Further research should be conducted to find out how biochar and NPK fertilizer when co-applied influence the nitrogen cycle to ensure availability of nitrogen in the soil to support plant growth and minimize inorganic fertilizers cost.

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APPENDICES

APPENDIX A: ANOVA Table for Plant Girth

Randomized Complete Block AOV Table for 3 WAP

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
REP stratum	2	0.16727	0.08363	1.59	
REP.*Units* stratum					
TREATMT	3	0.06249	0.02083	0.39	0.762
Residual	6	0.31653	0.05276		
Total	11	0.54629			

Randomized Complete Block AOV Table for 5 WAP

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
REP stratum	2	0.40647	0.20323	3.56	
REP.*Units* stratum					
TREATMT	3	0.07610	0.02537	0.44	0.730
Residual	6	0.34300	0.05717		
Total	11	0.82557			

Randomized Complete Block AOV Table for 7 WAP

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
REP stratum	2	0.38407	0.19203	2.30	
REP.*Units* stratum					
TREATMT	3	0.08822	0.02941	0.35	0.790
Residual	6	0.50140	0.08357		
Total	11	0.97369			

APPENDIX B: ANOVA Table for Number of Leaves

Randomized Complete Block AOV Table for 3 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	0.7292	0.2431	0.65	0.606
Residual	8	3.0000	0.3750		
Total	11	3.7292			

Randomized Complete Block AOV Table for 5 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	4.292	1.431	0.82	0.520
Residual	8	14.000	1.750		
Total	11	18.292			

Randomized Complete Block AOV Table for 7 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	4.432	1.477	0.97	0.451
Residual	8	12.125	1.516		
Total	11	16.557			

APPENDIX C: ANOVA Table for Leaf Width

Randomized Complete Block AOV Table for 3 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	0.3572	0.1191	0.24	0.863
Residual	8	3.8971	0.4871		
Total	11	4.2543			

Randomized Complete Block AOV Table for 5 WAP

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	0.857	0.286	0.13	0.938
Residual	8	17.199	2.150		
Total	11	18.055			

Randomized Complete Block AOV Table for 7 WAP

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	0.7824	0.2608	0.27	0.843
Residual	8	7.6362	0.9545		
Total	11	8.4186			

APPENDIX D: ANOVA Table for Leaf Length

Randomized Complete Block AOV Table for 3 WAP

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	33.60	11.20	0.31	0.819
Residual	8	291.11	36.39		
Total	11	324.71			

Randomized Complete Block AOV Table for 7 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	25.8	8.6	0.07	0.974
Residual	8	965.2	120.7		
Total	11	991.0			

APPENDIX E: ANOVA Table for Plant Height

Randomized Complete Block AOV Table for 3 WAP

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	9.693	3.231	0.59	0.640
Residual	8	43.953	5.494		
Total	11	53.646			

Randomized Complete Block AOV Table for 5 WAP

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	9.7	3.2	0.02	0.994
Residual	8	1034.1	129.3		
Total	11	1043.8			

Randomized Complete Block AOV Table for 7 WAP

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	912.0	304.0	0.48	0.702
Residual	8	5014.7	626.8		
Total	11	5926.7			

APPENDIX F: ANOVA Table for Germination Percentage

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
REP stratum	2	236.32595	118.16298	1206.60	
REP.*Units* stratum					
TREATMT	3	171.88137	57.29379	585.05	<.001
Residual	6	0.58758	0.09793		
Total	11	408.79490			

APPENDIX G: ANOVA Table for Days to 50% Tasseling

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	6.917	2.306	0.30	0.824
Residual	8	61.333	7.667		
Total	11	68.250			

APPENDIX H: ANOVA Table for Days to 50% Silking

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	9.583	3.194	0.35	0.789
Residual	8	72.667	9.083		
Total	11	82.250			

APPENDIX I: ANOVA Table for Days to 50% Maturity

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	98.2500	32.7500	56.14	<.001
Residual	8	4.6667	0.5833		
Total	11	102.9167			

APPENDIX J: ANOVA Table for Cob Weight

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	2774.	925.	0.85	0.503
Residual	8	8674.	1084.		
Total	11	11448.			

APPENDIX K: ANOVA Table for Cob Length

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
TREATMENT	3	9.8005	3.2668	3.80	0.058
Residual	8	6.8757	0.8595		
Total	11	16.6762			

APPENDIX L: ANOVA Table for Cob Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TREATMENT	3	0.11963	0.03988	0.46	0.716
Residual	8	0.68827	0.08603		
Total	11	0.80790			

APPENDIX M: ANOVA Table for 100 Seed Weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.021017	0.010508	1.27	
REP.*Units* stratum					
TREATMT	3	0.149233	0.049744	6.03	0.030
Residual	6	0.049517	0.008253		
Total	11	0.219767			

APPENDIX N: ANOVA Table for Rows per Cob

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	8.582	4.291	2.82	
REP.*Units* stratum					
TREATMT	3	1.522	0.507	0.33	0.802
Residual	6	9.145	1.524		
Total	11	19.249			

APPENDIX O: ANOVA Table for Grains per Cob

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	25781.	12890.	5.78	
REP.*Units* stratum					
TREATMT	3	17067.	5689.	2.55	0.152
Residual	6	13378.	2230.		
Total	11	56225.			